

### SUPPORT FOR THE AMENDMENT

This Amendment cancels Claims 2-3; amends Claims 1 and 4; and adds new Claims 23-27. Support for the amendments is found in the specification and claims as originally filed. In particular, support for Claims 1 is found in canceled Claims 2-3. Support for new Claim 23 is found in the specification at least at page 13, line 11. Support for new Claim 24 is found in the specification at least at page 13, line 25. Support for new Claim 25 is found in the specification at least at page 15, line 8. Support for new Claim 26 is found in the specification at least at page 19, line 14. Support for new Claim 27 is found in the specification at least at page 19, line 23. No new matter will be introduced by entry of these amendments.

Upon entry of these amendments, Claims 1 and 4-27 will be pending in this application. Claims 1, 8, 15, 16, 19 and 21 are independent. Claims 8-22 are withdrawn from consideration pursuant to a Restriction Requirement.

### REQUEST FOR RECONSIDERATION

Applicants respectfully request entry of the foregoing and reexamination and reconsideration of the application, as amended, in light of the remarks that follow.

The present invention provides a silicon carbide matrix composite material comprising a silicon carbide matrix and a silicon phase. The silicon carbide matrix comprises a first silicon carbide phase and a second silicon carbide phase. The silicon phase is continuously present in network form in interstices of silicon carbide crystal grains constituting the silicon carbide matrix. By controlling the microstructure of the silicon carbide matrix composite material, the present invention substantially improves the strength and fracture toughness of the silicon carbide matrix composite material. Specification at page 6, lines 1-6.

The silicon phase has a continuous network structure. When the silicon phase exists discontinuously, the segregation of the silicon phase is broken out in the composite material. Since the strength of the silicon phase is lower than that of the silicon carbide matrix, if the segregation of the silicon phase is broken out in the composite material, the strength of the composite material is degraded. See, e.g., specification at page 14, [0045].

The silicon phase has an average diameter in a range of 0.03 to 3  $\mu\text{m}$ . The mechanical properties of the composite material can be improved by controlling the microstructure of the silicon phase. The average diameter of the Si phase corresponds to an average distance between the silicon carbide crystal grains. The small average diameter of the silicon phase means that the silicon phase is miniaturized and uniformly distributed in the interstices of the silicon carbide crystal grains. Specification at [0047].

When the average diameter of the silicon phase is in the range of 0.03 to 3  $\mu\text{m}$ , a SiC matrix composite material having high strength and toughness can be obtained with good reproducibility. If the silicon phase has an average diameter of less than 0.03  $\mu\text{m}$ , it is difficult to maintain the network structure, a defect such as holes tends to occur, and the mechanical properties become unstable. Specification at [0048].

Claims 1-7 are rejected under 35 U.S.C. § 102(b) or, in the alternative, under 35 U.S.C. § 103(a) over U.S. Patent No. 4,019,913 ("Weaver").

Weaver discloses a method for fabricating reaction-bonded silicon carbide shapes. Weaver at column 3, lines 32-33. Weaver's process utilizes a mixture of silicon carbide powder and powdered carbon (e.g., colloidal graphite), each with an average particle size of less than 10 microns. Weaver at abstract; column 3, lines 35-39. The powder mixture is pressed into a desired shape, and fired at approximately 2000°C in the presence of silicon, converting the graphite to silicon carbide. Weaver at abstract.

However, Weaver is silent about and fails to suggest the average grain diameter of the silicon carbide formed by reaction between graphite and silicon (corresponding to independent Claim 1's "second silicon carbide phase") or the average grain diameter of the silicon after firing (corresponding to Claim 1's "silicon phase"). The Office Action at page 3, line 1, admits the "the grain sizes of the final article (sic) are not disclosed" in Weaver.

Yet, the Office Action at page 3, lines 1-3, asserts "the particle sizes and process of making [in Weaver] are not unlike that claimed therefore the claimed grain sizes would be inherent of the composite taught by Weaver et al".

On the contrary, Weaver's process is quite different than that used to produce the silicon matrix composite material of the present invention. Weaver's process uses much higher temperatures and vaporized Si. Weaver discloses:

If the shape to be made is relatively simple so that it may be formed directly by pressing, then the twice milled and dried silicon carbide-carbon molding powder is pressed to shape and either exposed to **silicon metal vapors** or contacted with **molten silicon at a temperature in excess of 2000°C**. This heat treatment causes densification of the original silicon carbide and the in situ formation of new silicon carbide. Weaver at column 3, line 64 to column 4, line 3 (emphasis added).

The melting point of silicon is 1410°C (= 1683 K); and the boiling point of silicon is 2355°C (= 2628 K). Hawley's Condensed Chemical Dictionary, Twelfth edition, page 1035 (copy attached).

The vapor pressure of silicon at 2000°C (= 2273 K) is almost 1 torr. Handbook of Thin Film Technology, pages 1-16 and 1-17 (copy attached).

At Weaver's temperatures in excess of 2000°C (= 2273 K), molten silicon becomes a vapor. The Si vapor does not penetrate substantially into Weaver's shaped SiC body as it is being fired. The Si vapor that remains in Weaver's SiC body does not form a continuous network structure and does not have an average diameter in a range of 0.03 to 3 µm.

In contrast to Weaver, the silicon carbide matrix composite material of the present invention is produced by impregnating a compact of silicon carbide powder and carbon powder with molten silicon at a temperature on the order of the melting point of silicon (~1400°C). See, e.g., specification at page 22, lines 19-21. In other words, Weaver impregnates with silicon at a temperature 600°C (= 2000°C - 1400°C) higher than the present invention.

Because the processes used in Weaver and the present invention are so different, the independent Claim 1 limitations of a "silicon carbide matrix composite material, comprising: a silicon carbide matrix which comprises a first silicon carbide phase having silicon carbide crystal grains with an average crystal grain diameter in a range of 0.1 to 10 µm and a *second silicon carbide phase* having silicon carbide crystal grains with an **average crystal grain diameter in a range of 0.01 to 2 µm**; and a *silicon phase* which is **continuously present in network form** in interstices of the silicon carbide crystal grains constituting the silicon carbide matrix, and has an **average diameter in a range of 0.03 to 3 µm**, wherein the composite material contains the silicon phase in a range of 5 to 50 mass%" are not inherent (i.e., necessarily present) in Weaver.

Because Weaver fails to suggest all of the limitations of independent Claim 1, the rejection over Weaver should be withdrawn.

Claims 1-7 are rejected under 35 U.S.C. § 102(b) or, in the alternative, under 35 U.S.C. § 103(a) over U.S. Patent No. 5,589,116 ("Kojima").

Kojima discloses a process for preparing a silicon carbide sintered body having sufficient purity for use in equipment for manufacturing semiconductor devices. Kojima at column 1, lines 10-13. Kojima's process comprises the steps of shaping a silicon carbide powder, calcining the shaped body in a non-oxidizing atmosphere to form a porous body, and subjecting the porous body to reaction sintering while being impregnated with molten

metallic silicon. Kojima at column 3, lines 28-34. Kojima discloses that the silicon carbide powder has a free carbon content of not greater than about 20% by weight. Kojima at column 3, lines 36-37. The free carbon is distributed in the form of carbon fine particles having a diameter of about 0.01-0.1  $\mu\text{m}$  around the polycrystalline particles of silicon carbide. Kojima at column 9, lines 5-12.

When the free carbon is distributed around the silicon carbide powder, the silicon carbide powder will be sintered easily, and the silicon carbide produced by the reaction of free carbon and silicon is condensed. As a result, the Si phase which exists in the interstices of the silicon carbide crystal grains is also condensed. In Kojima, the Si phase exists discontinuously, and the segregation of the Si phase is broken out in the silicon carbide sintered body.

Thus, Kojima fails to suggest the independent Claim 1 limitations of a "silicon carbide matrix composite material, comprising: ... a *silicon phase* which is **continuously present in network form** in interstices of the silicon carbide crystal grains constituting the silicon carbide matrix, and has an **average diameter in a range of 0.03 to 3  $\mu\text{m}$** , ...". Therefore, the rejection over Kojima should be withdrawn.

Claims 1 and 4 are rejected under 35 U.S.C. § 112, second paragraph. To obviate the rejection, Claims 1 and 4 are amended.

In view of the foregoing amendments and remarks, Applicants respectfully submit that the application is in condition for allowance. Applicants respectfully request favorable consideration and prompt allowance of the application.

Should the Examiner believe that anything further is necessary in order to place the application in even better condition for allowance, the Examiner is invited to contact Applicants' undersigned attorney at the telephone number listed below.

Respectfully submitted,

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Attached:

Hawley's Condensed Chemical Dictionary, Twelfth edition, page 1035  
Handbook of Thin Film Technology, pages 1-16 and 1-17

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conditioning, drying of compressed air and other gases, and liquids, such as refrigerants and oils containing water in suspension, recovery of natural gasoline from natural gas, bleaching of petroleum oils, catalyst and catalyst carrier, chromatography, anti-caking agent in cosmetics and pharmaceuticals, in waxes to prevent slipping, in dietary supplements.  
See also silicic acid, "Britesorb" [PQ Corp.].

**"Silic AR"** [Mallinckrodt]. TM for silica-gel-based formulations, suitable for various chromatographic applications. The numerical suffixes indicate the approximate pH of a 10% slurry. Letters F, G, or GF indicate that the product contains a fluorescent material, gypsum binder, or both. "TLC" indicates suitability for thin-layer chromatography.

**silicate.** Any of the widely occurring compounds containing silicon, oxygen, and one or more metals with or without hydrogen. The silicon and oxygen may combine with organic groups to form silicate esters. Most rocks (except limestone and dolomite) and many mineral compounds are silicates. Typical natural silicates are gemstones (except diamond), beryl, asbestos, talc, clays, feldspar, mica, etc. Portland cement contains a high percentage of calcium silicates. Best known of the synthetic (soluble) silicates is sodium silicate (water glass).

**Hazard** (natural silicate dusts): Toxic by inhalation.

**Use:** Fillers in plastics and rubber, paper coatings, antacids, anticaking agents, cements.

**silicate garden.** The irregular, colored tubular growths formed in dilute aqueous silicate solutions by dropping water solutions of heavy metal salts into them.

**silicic acid.** (hydrated silica). CAS: 7699-41-4.

$\text{SiO}_2 \cdot n\text{H}_2\text{O}$ . The jelly-like precipitate obtained when sodium silicate solution is acidified. The proportion of water varies with the conditions of preparation and decreases gradually during drying and ignition, until relatively pure silica remains. During drying the jelly is converted to a white amorphous powder or lumps.

**Use:** Laboratory reagent and reinforcing agent in rubber.

See silica gel.

**silicochloroform.** See trichlorosilane.

**silicol.** Silicic oxide casein metaphosphate.

**silicomanganese.** Alloys consisting principally of manganese, silicon, and carbon.

**Use:** Low-carbon steel in which silicon is not ob-

jectionable. Silicon manganese steels are used for springs and high-strength structural steels.  
See also manganese steels and ferromanganese.

**silicomolybdic acid.** See 12-molybdosilicic acid.

**silicon.** Si. Nonmetallic element Atomic number 14, group IVA of the periodic table, aw 28.086, valence = 4, three stable isotopes. It is the second most abundant element (25% of the earth's crust) and is the most important semiconducting element; it can form more compounds than any other element except carbon.

**Properties:** Dark-colored crystals (the octahedral form in which the atoms have the diamond arrangement). The amorphous form is a dark brown powder (see silicon, amorphous). Soluble in a mixture of nitric and hydrofluoric acids and in alkalis; insoluble in water, nitric acid, and hydrochloric acid. D 2.33, mp 1410C, bp 2355C, Mohs hardness 7, dielectric constant 12, coordination number 6. Combines with oxygen to form tetrahedral molecules in which one silicon atom is surrounded by four oxygen atoms. In this respect, it is similar to carbon. It is also capable of forming  $\text{—Si=Si—}$  double bonds in organosilicon compounds.

**Occurrence:** Does not occur free in nature, but is a major portion of silica and silicates (rocks, quartz, sand, clays, etc.).

**Derivation:** Crystalline silicon is made commercially (96–98% pure) in an electric furnace by heating  $\text{SiO}_2$  with carbon, followed by zone refining. It can be purified to 99.7% by leaching. The ultra-pure semiconductor grade (99.97%) is obtained by reduction of purified silicon tetrachloride or trichlorosilane with purified hydrogen; the silicon is deposited on hot filaments (800C) of tantalum or tungsten. In a one-step method, sodium fluorosilicate is reacted with sodium, the heat produced being sufficient to form silicon tetrafluoride; this, when reacted with sodium, yields high-purity silicon and sodium fluoride. The process requires no heat except that provided by the original reaction. Single crystals of both n- and p-type are grown by highly specialized techniques.

**Grade:** Ferrosilicon, regular (97% silicon), semiconductor or hyperpure (99.97% silicon), amorphous.

**Hazard:** Flammable in powder form.

**Use:** Semiconductor in solid-state devices (transistors, photovoltaic cells, computer circuitry, rectifiers, etc.); organosilicon compounds; silicon carbide; alloying agent in steels, aluminum, copper, bronze, and iron (ferrosilicon); cermets and special refractories; halogenated silanes; spring steels; deoxidizer in steel manufacture.  
See also silica; silicate; silicone; ferrosilicon; silicon, amorphous.

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TABLE 2 Vapor-pressure Data for the Solid and Liquid Elements\*

			Temperatures (°K) for vapor pressures, torr															
Symbol	Element	Data temp range, °K	10 <sup>-11</sup>	10 <sup>-10</sup>	10 <sup>-9</sup>	10 <sup>-8</sup>	10 <sup>-7</sup>	10 <sup>-6</sup>	10 <sup>-5</sup>	10 <sup>-4</sup>	10 <sup>-3</sup>	10 <sup>-2</sup>	10 <sup>-1</sup>	1	10 <sup>1</sup>	10 <sup>2</sup>	10 <sup>3</sup>	
Ac	Actinium	1873, est.	1045	1100	1160	1230	1305	1390	1490	1605	1740	1905	2100	2350	2660	3030	3510	
Ag	Silver	958-2200	721	759	800	847	899	958	1025	1105	1195	1300	1435	1605	1815	2100	2490	
Al	Aluminum	1220-1468	815	860	906	958	1015	1085	1160	1245	1355	1490	1640	1830	2050	2370	2800	
Am	Americium	1103-1453	712	752	797	848	905	971	1050	1140	1245	1375	1540	1745	2020	2400	2970	
As	Arsenic(s)		323	340	358	377	400	423	447	477	510	550	590	645	712	795	900	
As <sub>4</sub>	Astatine	Est.	221	231	241	252	265	280	296	316	338	364	398	434	480	540	620	
Au	Gold	1073-1847	915	964	1020	1080	1150	1220	1305	1405	1525	1670	1840	2040	2320	2680	3130	
B	Boron	1781-2413	1335	1405	1480	1555	1640	1740	1855	1980	2140	2300	2520	2780	3100	3500	4000	
Ba	Barium	1333-1419	450	480	510	545	583	627	675	735	800	883	984	1125	1310	1570	1930	
Be	Beryllium	1103-1552	832	878	925	980	1035	1105	1180	1270	1370	1500	1650	1830	2080	2390	2810	
Bi	Bismuth		510	540	568	602	640	682	732	790	860	945	1050	1170	1350	1570	1900	
Bi	Carbon(s)	1820-2700	1695	1765	1845	1930	2030	2140	2260	2410	2560	2730	2930	3170	3450	3780	4190	
Ca	Calcium	730-1546	470	495	524	555	590	630	678	732	795	870	962	1075	1250	1475	1800	
Cd	Cadmium	411-1040	293	310	328	347	368	392	419	450	490	538	593	665	762	885	1060	
Ce	Cerium	1611-2038	1050	1110	1175	1245	1325	1420	1525	1650	1795	1970	2180	2440	2780	3220	3830	
Co	Cobalt	1363-1522	1020	1070	1130	1195	1265	1340	1430	1530	1655	1790	1960	2180	2440	2790	3220	
Cr	Chromium	1273-1557	960	1010	1055	1110	1175	1250	1335	1430	1540	1670	1825	2010	2240	2550	3000	
Cs	Cesium	300-955	213	226	241	257	274	297	322	351	387	428	482	553	643	775	980	
Cu	Copper	1143-1897	855	895	945	995	1060	1125	1210	1300	1405	1530	1690	1890	2140	2460	2920	
Dy	Dysprosium	1258-1773	760	801	847	898	955	1020	1090	1170	1270	1390	1535	1710	1965	2300	2780	
Er	Erbium	1773, est.	779	822	869	922	981	1050	1125	1220	1325	1450	1605	1800	2060	2420	2920	
Eu	Europium	696-900	469	495	523	556	592	634	682	739	805	884	981	1100	1260	1500	1800	
Fr	Francium	Est.	198	210	225	242	260	280	306	334	368	410	462	528	620	760	980	
Fe	Iron	1356-1889	1090	1050	1105	1165	1230	1305	1400	1500	1615	1750	1920	2130	2390	2740	3200	
Ga	Gallium(l)	1179-1383	755	796	841	892	950	1015	1090	1180	1280	1405	1555	1745	1980	2300	2730	
Gd	Gadolinium	Est.	880	930	980	1035	1100	1170	1250	1350	1465	1600	1760	1955	2220	2580	3100	
Ge	Germanium	1510-1885	940	980	1030	1085	1150	1220	1310	1410	1530	1670	1830	2050	2320	2680	3180	
Hf	Hafnium	2035-2277	1505	1580	1665	1760	1865	1980	2120	2270	2450	2670	2930	3240	3630	4130	4780	
Hg	Mercury	193-575	170	180	190	201	214	229	246	266	289	319	353	398	458	535	642	
Ho	Holmium	923-2023	779	822	869	922	981	1050	1125	1220	1325	1450	1605	1800	2060	2410	2910	
In	Indium(l)	646-1348	641	677	716	761	812	870	937	1015	1110	1220	1355	1520	1740	2030	2430	
Ir	Iridium	1986-2600	1585	1665	1755	1850	1960	2080	2220	2380	2560	2770	3040	3360	3750	4250	4900	
K	Potassium	373-1031	247	260	276	294	315	338	364	396	434	481	540	618	720	858	1070	
La	Lanthanum	1655-2167	1100	1155	1220	1295	1375	1465	1570	1695	1835	2000	2200	2450	2760	3150	3680	
Li	Lithium	735-1353	430	452	480	508	541	579	623	677	740	810	900	1020	1170	1370	1620	
Lu	Lutetium	Est.	1000	1060	1120	1185	1260	1345	1440	1550	1685	1845	2030	2270	2550	2910	3370	
Mg	Magnesium	626-1376	388	410	432	458	487	519	555	600	650	712	782	878	1000	1170	1400	

Mn	Manganese	1523-1823	660	695	734	778	827	884	948	1020	1110	1210	1335	1490	1695	1970	2370
Mo	Molybdenum	2070-2504	1610	1690	1770	1865	1975	2095	2230	2390	2580	2800	3060	3390	3790	4300	5020
Na	Sodium	496-1156	294	310	328	347	370	396	428	466	508	562	630	714	825	978	1175
Nb	Niobium	2304-2596	1765	1845	1935	2035	2140	2260	2400	2550	2720	2930	3170	3450	3790	4200	4710
Nd	Neodymium	1240-1600	846	895	945	1000	1070	1135	1220	1320	1440	1575	1770	2000	2300	2740	3430
Ni	Nickel	1307-1895	1040	1090	1145	1200	1270	1345	1430	1535	1655	1800	1970	2180	2430	2770	3230
Os	Osmium	2300-2900	1875	1965	2060	2170	2290	2430	2580	2760	2960	3190	3460	3800	4200	4710	5340
P	Phosphorus(s)		283	297	312	327	342	361	381	402	430	458	493	534	582	642	715
Pb	Lead	1200-2028	516	546	580	615	656	702	758	820	895	988	1105	1250	1435	1700	2070
Pd	Palladium	1294-1640	945	995	1050	1115	1185	1265	1355	1465	1590	1735	1920	2150	2450	2840	3380
SPo	Polonium	711-1286	332	348	365	384	408	432	460	494	537	588	655	743	862	1040	1250
Pr	Praseodymium	1423-1693	900	950	1005	1070	1140	1220	1315	1420	1550	1700	1890	2120	2420	2820	3370
Pt	Platinum	1697-2042	1335	1405	1480	1565	1655	1765	1885	2020	2180	2370	2590	2860	3190	3610	4170
Pu	Plutonium(I)	1392-1793	931	983	1040	1105	1180	1265	1365	1480	1615	1780	1975	2230	2550	2980	3590
Ra	Radium	Est.	436	460	488	520	552	590	638	690	755	830	920	1060	1225	1490	1840
Rb	Rubidium		227	240	254	271	289	312	336	367	402	446	500	568	665	802	1000
Re	Rhenium	2494-2999	1900	1995	2100	2220	2350	2490	2660	2860	3080	3340	3680	4080	4600	5220	6050
Rh	Rhodium	1709-2205	1330	1395	1470	1550	1640	1745	1855	1980	2130	2310	2520	2780	3110	3520	4070
Ru	Ruthenium	2000-2500	1540	1610	1695	1780	1880	1990	2120	2260	2420	2620	2860	3130	3480	3900	4450
SS	Sulfur		230	240	252	263	276	290	310	328	353	382	420	462	519	606	739
SSb	Antimony	693-1110	477	498	526	552	582	618	656	698	748	806	885	1030	1250	1560	1960
Sc	Scandium	1301-1780	881	929	983	1045	1110	1190	1280	1380	1505	1650	1835	2070	2370	2780	3360
SSe	Selenium	550-950	286	301	317	336	356	380	406	437	472	516	570	636	719	826	972
SSi	Silicon	1640-2054	1090	1145	1200	1265	1340	1420	1510	1610	1745	1905	2090	2330	2620	2900	3490
Sm	Samarium	789-833	542	573	608	644	688	738	790	853	926	1015	1120	1260	1450	1715	2120
Sn	Tin(I)	1424-1753	805	852	900	955	1020	1080	1170	1270	1380	1520	1685	1885	2140	2500	2960
Sr	Strontium		433	458	483	514	546	582	626	677	738	810	900	1005	1160	1370	1680
Ta	Tantalum	2624-2948	1930	2020	2120	2230	2370	2510	2680	2860	3080	3330	3630	3980	4400	4930	5580
Tb	Terbium	Est.	900	950	1005	1070	1140	1220	1315	1420	1550	1700	1890	2120	2420	2820	3370
Tc	Technetium	Est.	1580	1665	1750	1840	1950	2060	2200	2350	2530	2760	3030	3370	3790	4300	5000
Te	Tellurium	481-1128	306	385	405	428	454	482	515	553	596	647	706	791	905	1065	1300
Th	Thorium	1757-1956	1450	1525	1610	1705	1815	1935	2080	2250	2440	2680	2960	3310	3750	4340	5130
Ti	Titanium	1510-1822	1140	1200	1265	1335	1410	1500	1600	1715	1850	2010	2210	2450	2760	3130	3640
Tl	Thallium	519-924	473	499	527	556	592	632	680	736	803	882	979	1100	1255	1460	1750
Tm	Thulium	809-1219	624	655	691	731	776	825	882	953	1030	1120	1235	1370	1540	1760	2060
U	Uranium	1630-2071	1190	1255	1325	1405	1495	1600	1720	1855	2010	2200	2430	2720	3080	3540	4180
V	Vanadium	1666-1882	1235	1295	1365	1435	1510	1605	1705	1820	1960	2120	2320	2560	2850	3220	3720
W	Tungsten	2518-3300	2050	2150	2270	2390	2520	2680	2840	3030	3250	3500	3810	4180	4630	5200	5900
Y	Yttrium	1774-2103	1045	1100	1160	1230	1305	1390	1490	1605	1740	1905	2105	2355	2670	3085	3650
Yb	Ytterbium	Est.	436	460	488	520	552	590	638	690	755	830	920	1060	1225	1490	1840
Zn	Zinc	422-1089	336	354	374	396	421	450	482	520	565	617	681	760	870	1010	1210
Zr	Zirconium	1949-2034	1500	1580	1665	1755	1855	1975	2110	2260	2450	2670	2930	3250	3650	4170	4830

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# Handbook of Thin Film Technology

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